DEPARTMENT OF PHYSICS AND ASTRONOMY
UNIVERSITY OF MASSACHUSETTS
NASA GRANT NAGW-436

4P

BOUNDARY CONDITIONS FOR THE PALEOENVIRONMENT: CHEMICAL AND PHYSICAL PROCESSES IN THE PRE-SOLAR NEBULA

SEMI-ANNUAL STATUS REPORT NO. 23
FEBRUARY 16, 1994 - AUGUST 15, 1994

Principal Investigator: William M. Irvine
Co-Principal Investigator: F. Peter Schloerb

Current Research

Graduate student D. McGonagle continued his study of interstellar nitrogen chemistry, with particular emphasis on the study of the NS radical in giant molecular clouds. Survey observations in the Milky Way Galaxy have been compared with the results of statistical equilibrium calculations of the excitation of NS in order to determine abundances in the observed clouds. NS is quite widely distributed in such regions.

McGonagle and L. Ziurys (Arizona State University) are completing their analysis of data taken in the first spectral survey of the 2mm wavelength region toward a giant molecular cloud. In particular, they have observed the Kleinmann-Low region of the Orion molecular cloud from 150-170 GHz. The results for the first 10 GHz of this range have been published, and the data for the second 10 GHz have been reduced and prepared for publication.

One of the few observational probes of the effects of interstellar grains on the chemistry of molecular clouds comes from the measurement of the ortho/para ratio for species such as

formaldehyde. Interpretation of previous data is suspect, however, because relevant transitions for the most abundant isotopic variant of formaldehyde are optically thick. Irvine, Y. Minh (Korean Astronomical Observatory), and D. McGonagle observed carbon 13 formaldehyde with the NRAO 12m telescope in Arizona, achieving the first astronomical detection of this isotopic species in cold, dark molecular clouds. The $H_2{}^{13}CO$ ortho/para ratio R for the Bok globule B335 was found to be $R \approx 1.7$, suggesting equilibrium at the local kinetic temperature and hence exchange of material between grain mantles and the gas phase. In contrast, R was distinctly higher for both the clouds TMC-1 and L134N, being close to or larger than the ratio of statistical weights which would correspond to the high temperature limit (3). The latter result is in conflict with earlier estimates of R, obtained by observing the optically thick $H_2{}^{12}CO$ lines. Since only the position in B335 includes an embedded IR source, these results suggest that the embedded star may have heated the grain surfaces, providing the energy necessary for desorption of formaldehyde formed on the grains in B335.

A major project at the Five College Radio Astronomy Observatory was begun with the aim of carrying out a chemical mapping of cold, dark molecular clouds in many molecular transitions. Some thirty transitions will be observed over extended regions of the dark clouds TMC-1 and L134N. Chemical gradients will be compared to gradients in physical quantities such as temperature and density which can also be deduced from the data. The results will be compared with the previous survey of giant molecular clouds containing regions of active star formation. Irvine, Postdoctoral Research Associate P. Pratap, and graduate student J. Dickens are involved in this research.

Pratap completed work on a study of interstellar formaldehyde masers in galactic molecular clouds.

Papers supported by this grant and published during the period of this report:

1. "Detection of a New Interstellar Molecule CH_2N", Ohishi, M., Yamamoto, S., Saito, S., McGonagle, D., and Irvine, W.M., Ap. J., 427, L51 (1994).

2. "Search for H_2COH^+ and $H_2{}^{13}CO$ in Dense Interstellar Molecular Clouds", Minh, Y.C., Irvine, W.M., and McGonagle, D, J. Korean Ast. Soc., 26, 99 (1993).

Research supported by this grant currently in press:

1. "Organic Molecules in the Gas Phase of Dense Interstellar Clouds", Irvine, W.M., Adv. Space Res., in press (1993).

2. "Astronomy at Millimeter Wavelengths", Irvine, W.M., Schloerb, F.P., Schneider, S.E., and Snell, R.L., in Proc. INAOE Jubilee Symp., (1993).

3. "Observations of Small Nitrogen-Containing Molecules in Dark Clouds: NO, NS and H_2CN", Irvine, W., McGonagle, D., Ohishi, M., Yamamoto, S., and Saito, S., in Proc. Second Zermatt Conf. Interstellar Clouds, ed. J. Stutzki, in press.

4. "Observations of Molecular Envelopes of Late Type Stars: CRL 618, CRL 2688, CRL 3068 and CIT 6", Fukasaku, S., Hirahara, Y., Masuda, A., Kawaguchi, K., Ishikawa, S., Kaifu, N., and Irvine, W.M., Ap. J., in press.

5. "Chemical and Physical Gradients along the OMC-1 Ridge", Ungerechts, H., Bergin, E.A., Goldsmith, P.F., Irvine, W.M., Schloerb, F.P., and Snell, R.L., in Proc. Second Zermatt Conf. Interstellar Clouds, ed. J. Stutzki, in press.

6. "Measurements of the $H_2{}^{13}CO$ Ortho/para Ratio in Cold, Dark Molecular Clouds", Minh, Y.C., Dickens, J.E., Irvine, W.M., and McGonagle, D., Ast. Astrophys., submitted.

7. "Detection of Formaldehyde Maser Emission near the Ultraviolet Compact HII Region G29-96-0.02", Pratap, P., Menten, K.M., and Snyder, L.E., Ap. J., in press.

Future Plans

McGonagle will complete his study of interstellar nitrogen chemistry. It is expected that he will have finished all requirements for the Ph.D. by November, 1994.

The FCRAO Dark Cloud Chemistry Survey will continue under the direction of P. Pratap. Substantial observing time is expected using the 15-element QUARRY focal plane array at the Five College Radio Astronomy Observatory this winter.

The molecular oxiranecarbonitrile may play a key role in prebiological molecular evolution. Observing proposals to search for interstellar oxiranecarbonitrile have been submitted to the Nobeyama Radio Observatory in Japan and the Haystack Observatory in the United States. Both of these proposals have been granted observing time, and we expect these searches to begin during the coming six months.

Pratap and graduate student E. Bergin have submitted a proposal for observations with the ESA Infrared Space Observatory to "Probe the Molecular Content of the Interstellar

Medium". Specifically, they propose to observe the 2.6-5.0 micron spectral region with the ISO shortwave spectrometer along lines of sight to Rho Oph or Taurus. This range includes the solid state absorption features of numerous astrophysically interesting species, including CO, CH_3OH, CO_2, H_2S, OCS, NH_3, and CH_4. Observed data would be analyzed together with FCRAO observations of optically thin millimeter emission lines of the same molecules to characterize the total amount of molecular material along these lines of sight, and its partition between the solid and gas phases.

Irvine continues his participation in an unbiased spectral survey of the galactic center molecular cloud Sgr B2 being undertaken in collaboration with Swedish colleagues at the Swedish-European Submillimeter Telescope in Chile.

William M. Irvine
Principal Investigator

F. Peter Schloerb
Co-Principal Investigator

September 16, 1994